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ABSTRACT

The higher education accountability requirements of today cry for responsive models that describe the attitudes, perceptions and characteristics of the populations they serve. Trend Surface Analysis is such a model. It is simple to apply, analytical in nature, and results in a graphic display in the form of a map. To the extent that the description of the population reflects demands on higher education and the degree to which regional characteristics are helpful is the level of utility of Trend Surface Analysis. Trend Surface Analysis and other mapping techniques offer significant potential for providing information regarding broad regional bases. Even though all of the information displayed in the contour maps is available in a number of tables, the interpretation of these data is greatly simplified when viewed as a map. A second advantage is the ability to compare data drawn from various sources. Universities as well as other large public concerns need to sense the desires of the populations they serve. Studies of public demand are the first step on the road to accountability. Trend Surface Analysis offers a promising technique for interpreting the large volumes of data that accompany statewide assessment. (Author)

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THE PEOPLE OF THE STATE:

A Description Through Trend Surface Analysis

Donald N. McIsaac

The higher education accountability requirements of today cry for responsive models which describe the attitudes, perceptions and characteristics of the populations they serve. Trend Surface analysis is such a model. It is simple to apply, analytical in nature and results in a graphic display in the form of a map. In this paper, I wish to demonstrate its application to the complex decisions which must be made. To the extent that the description of the population reflects demands on higher education and the degree to which regional characteristics are helpful is the level of utility of trend surface analysis.

The Methodology of Trend Surface Analysis

There is not sufficient time to explore the mathematics of the approach to any great depth. A most helpful document which covers the topic can be found in the field of geography by Chorley (1965). There are, in fact, many approaches to the problem of areal display of data but the one which appears to have significant potential involves the computation of a curvilinear regression surface using a high order polynominal. The coordinates of the geographic location take the role of the independent variable. Data are often ordered according to county boundaries. The geographic centers of the counties were then measured and each becomes the independent attribute for the county. The methodology has the advantage of rendering comparable results based upon geographic centers of political districts, telephone exchanges or some other convenient method for organizing

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or collecting data. The station then becomes that point which represents the geographic center of the small area.

The variables selected from the station are the dependent variable. These variables might be the results of a questionnaire, a compilation of census data, a telephone survey or some other acceptable means of collecting data. The relationship of the dependent variable to the independent variables (Y coordinates) can best be described in the following equation.

$$Y = C_1 + C_2U + C_3V + C_4U^2 + C_5 UV + C_1V^2 .....$$

The equation is resolved for the values of the coefficients (C_1, C_2, C_3....). A program for this solution was developed by the author and is based upon the earlier work of McIntyre (1963). There are several other computer programs available for the solution of high order polynominals.

Once the regression (Trend Surface) has been computed, the equation can be employed to produce a grid of the entire region. The grid may then serve as input to a contour plotting package in order to produce visual displays of the data. Regional trends of the data may then be observed.

The contour depictions reflect the broad low frequency trends and admit to error regarding local chance variation. The contour maps and the trend surface analysis permits one to say very little about specific stations. Residuals are computed for each station which reflect the deviation each has from the general trend. Examination of these residuals permits interpretation of local effects.

An analysis of the April 7 Milwaukee School Bond election serves as a useful example, the map in Figure 1 is the result of a trend surface analysis where the precinct centers were measured for the set of independent variables U and V. The percent voting for the issue makes up the dependent variable. We can see that the heaviest support comes from the central urban part of the city. As one approaches the city limits in all directions there is evidence of a drop in support. The overall trend is one which

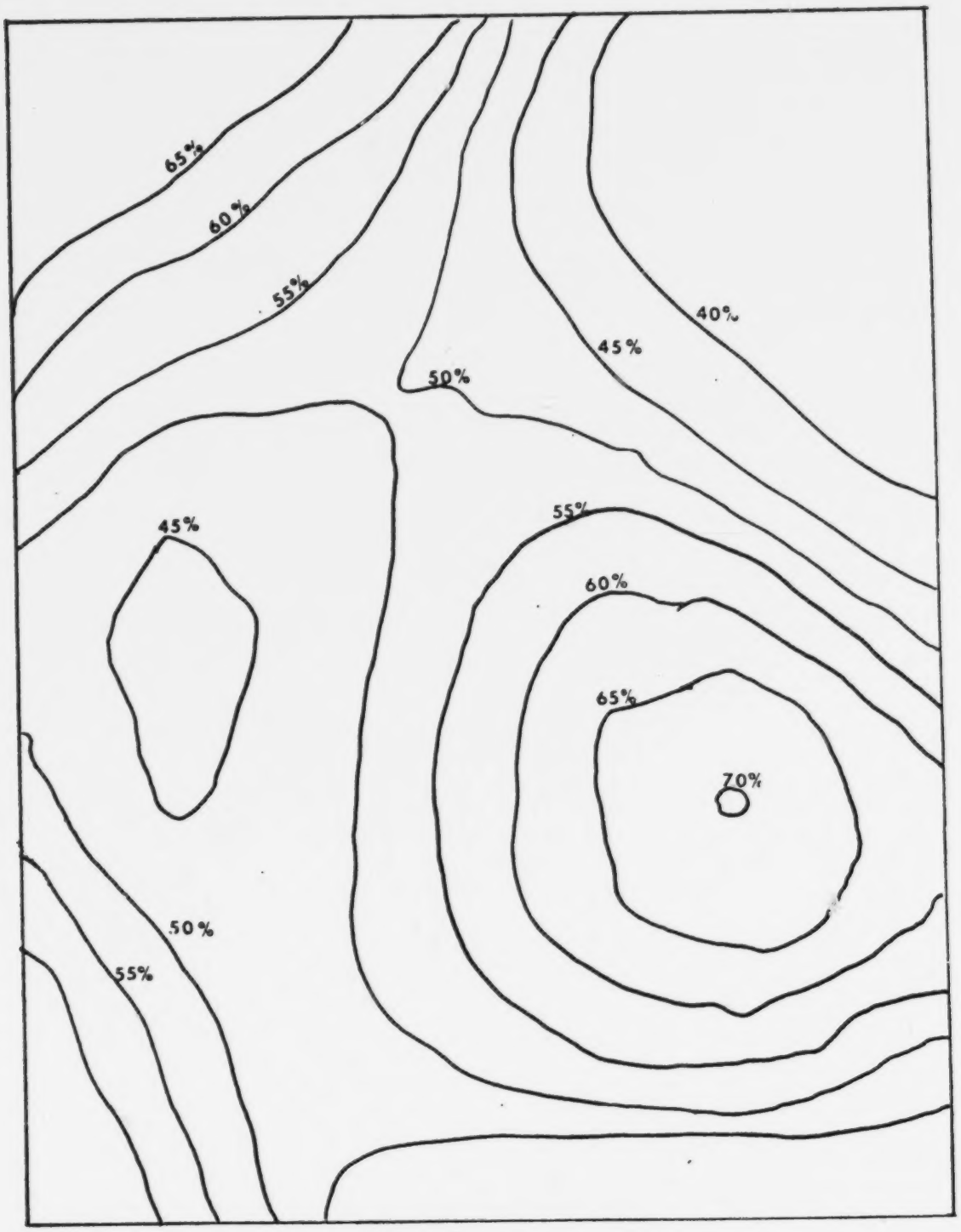

Figure 1

PERCENT IN FAVOR OF MILWAUKEE, APRIL 1970 BOND ELECTION

explains approximately forty percent of the total variance which is not excessively high. The residuals help us see where the map fails to reveal local effects. Ward 14 Precinct 1 has a 26% residual. This means that while one would expect about 56% support based upon the model, only 30% of the voters supported the issue. Ward 14 is located just west of the high support area of the city. Further study of the specific precinct involved would be required to determine exact causes. They may be related to the quality of the educational program in the area.

The trend surface depiction illustrates the application to political data. The raw data values are simple to collect and are often a matter of public record. It is useful to examine the application to broader geographic issues.

State-Wide Assessment of Population Attitudes

As a part of a Wisconsin Needs Assessment conducted in 1969, 1055 interviews were held in 40 randomly selected school districts in the State. (See Lipham, 1969). The interview sample was stratified by type of respondent. Two of the strata included citizens and school boards. During the interview, each respondent was asked to rank what he considered to be the needs of Education. One of the ranked issues was the need for programs for students terminating their education with high school. The two maps on the following pages (figures 2 and 3) illustrate the different regional perceptions held by citizens and school board members.

The central portion of the state reveals a relatively flat surface on each map with substantial agreement that such programs are only a mild responsibility of the State's educational program. Interestingly, as one moves toward the South and North-East regions of the state, agreement is

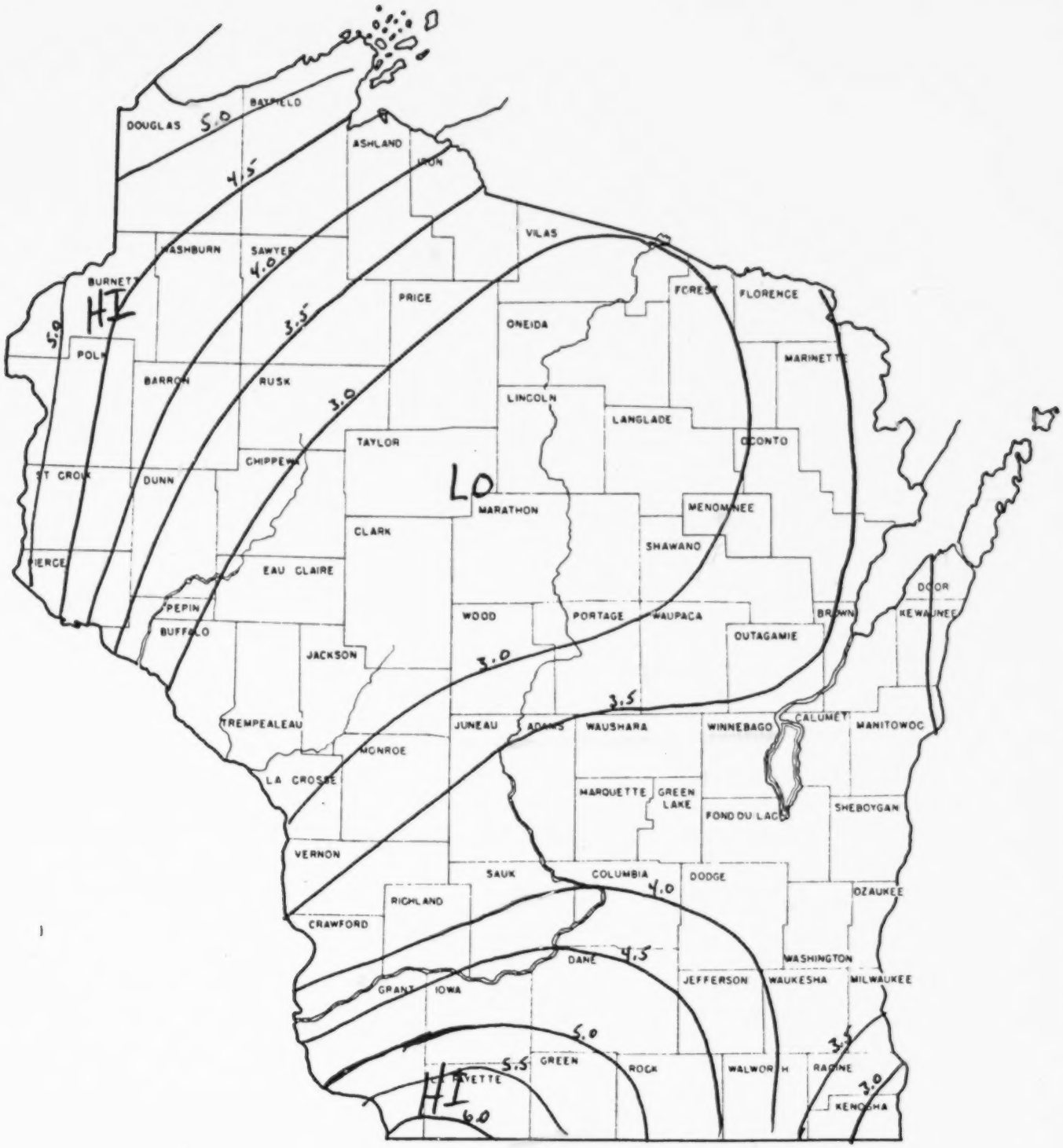

Figure 2

NEED FOR PROGRAMS FOR STUDENTS TERMINATING EDUCATION WITH HIGH SCHOOL - AS PERCEIVED BY CITIZENS

LOW NUMBER = HIGH NEED

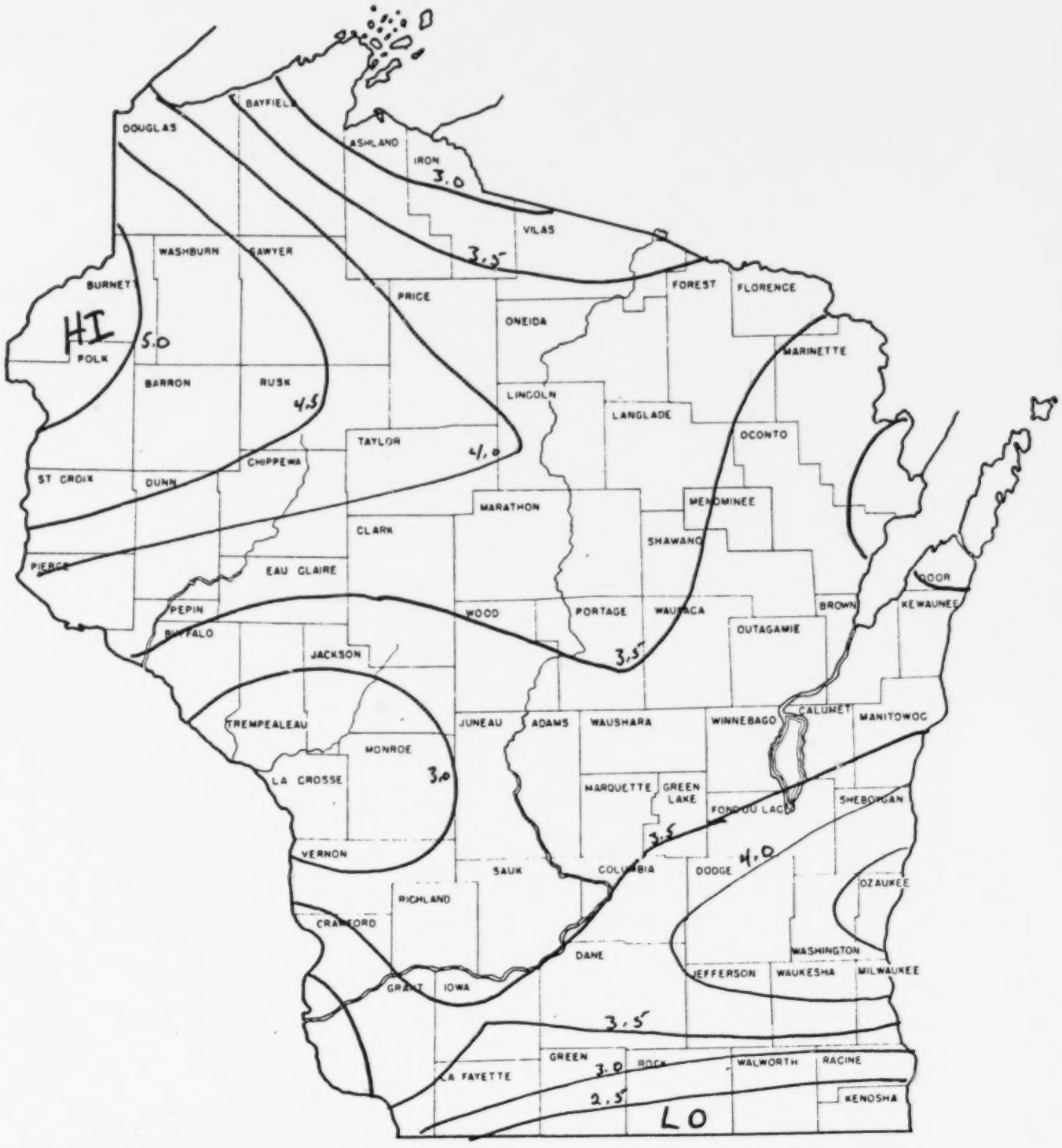

Figure 3

NEED FOR PROGRAMS FOR STUDENTS TERMINATING EDUCATION WITH HIGH SCHOOL - AS PERCEIVED BY SCHOOL BOARDS

LOW NUMBER = HIGH NEED

highly divided. School Boards tended to recognize a slightly decreasing desire in the Southeast, while citizens placed such programs at a very low priority. Citizens in the Southeast placed a high priority on terminal education programs, while school boards felt they were less important. The Northern region of the State shows some disagreement between the two groups. Citizens in the Northern Region rank terminal education as an extremely low priority while School Boards felt such programs were important. These divergencies do not make the decision process simple, but it does illustrate that the decision makers in the north may not have their pulse on local community perceptions.

The implications for higher education are evident. The constituent of the north or southeast may look with favor on efforts to develop a higher education opportunity for their youth. The urban citizen, on the other hand, may be seeking additional career specific programs in public schools.

A second aspect of the Wisconsin study related to the perceived need for vocational-technical programs. The attitudes of a state constituency bears some relation to the requirements for planning a system of higher education. True, not all the evidence can be contained within these analyses, but regional differences are an important consideration. Respondents were asked to rank the importance they place upon vocational-technical programs. In this instance, we see some striking similarities between the perceptions of citizens and school boards. Moving from the Southwest toward the Northeast, both groups identified vocational-technical education a low priority in the Southwest and a high priority in the Northeast. The adult population appears to be in significant agreement across the broad regions of the State (See figures 4 and 5). Students, on the other hand, saw things differently. The students of the Southwest region rated courses in

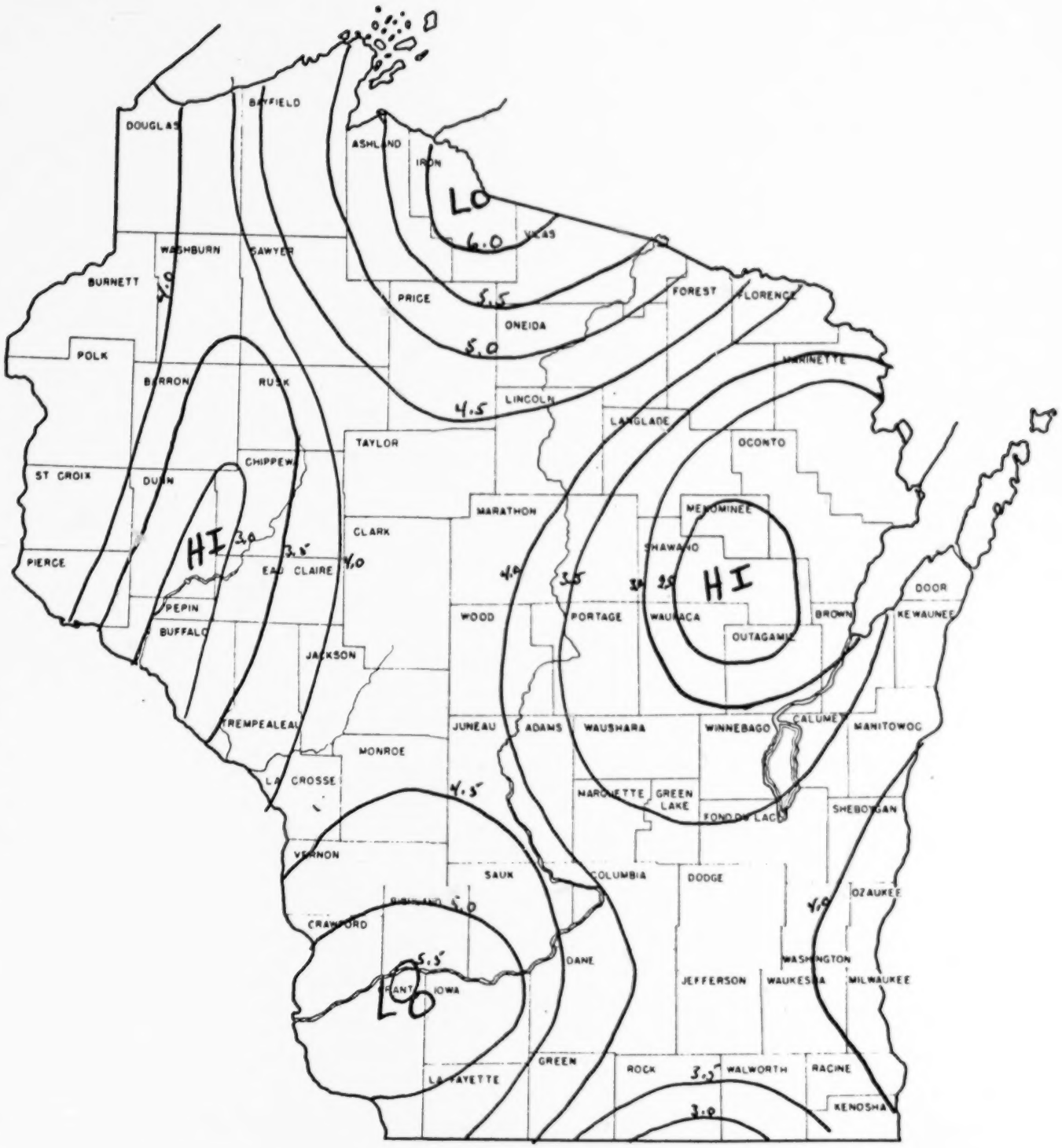

Figure 4

NEED FOR VOCATIONAL-TECHNICAL PROGRAMS AS PERCEIVED BY SCHOOL BOARDS

LOW NUMBER = HIGH NEED

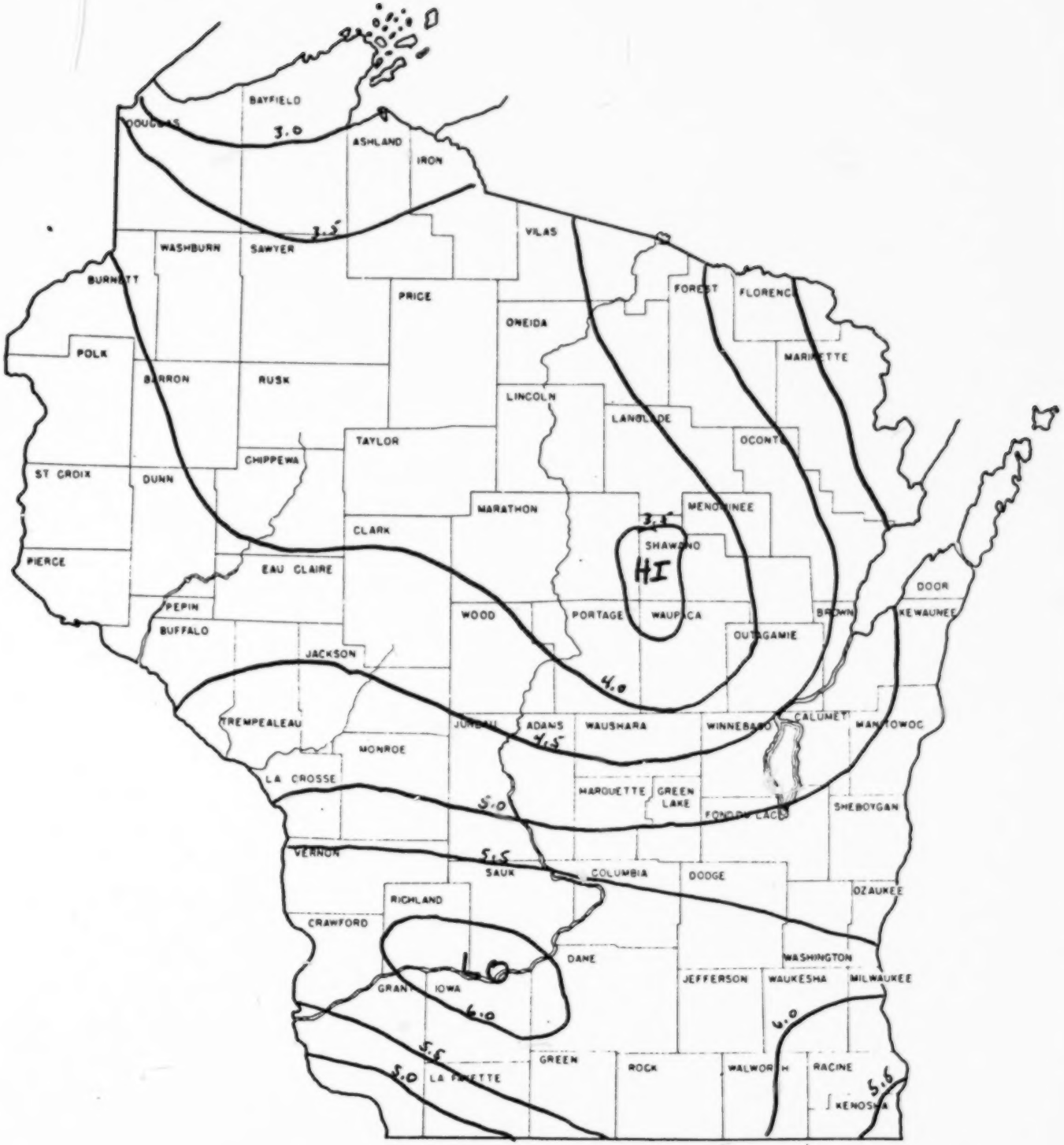

Figure 5

NEED FOR VOCATIONAL-TECHNICAL PROGRAMS AS PERCEIVED BY CITIZENS

LOW NUMBER = HIGH NEED

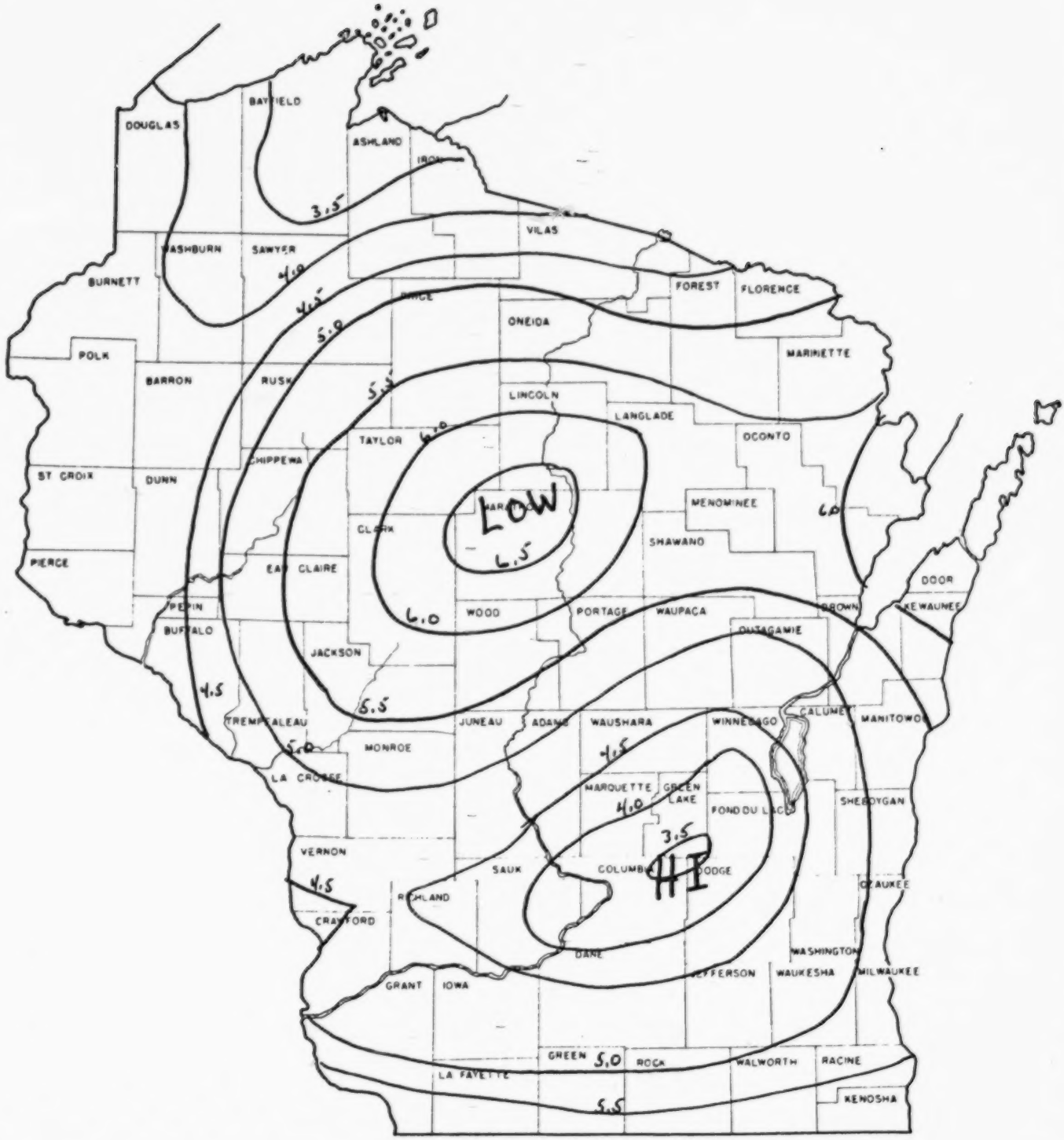

Figure 6

NEED FOR VOCATIONAL-TECHNICAL PROGRAMS AS PERCEIVED BY STUDENTS

LOW NUMBER = HIGH NEED

vocational-technical education as a high priority while those in the central and northern regions rated such programs of little value. (See Figure 6). The methodology does not speak to cause and effect in the same manner that correlational studies do not. To reiterate, generally school boards and citizens in the northern part of the State felt a greater need for emphasis on vocational-technical education than did their counterparts in the southern part of the state. For students, the trend generally was opposite (with the exception of a small band of concern on the part of students in the vicinity of Ashland-Superior). These findings might be of special interest to statewide policy makers and planners - particularly in the field of vocational-technical education.

Statewide Assessment of Income and Tax Characteristics

One of the attributes useful for the decisions in higher education is personal income, which to a large measure identifies the ability of a region to pay for services. The measure employed in this paper is the Wisconsin taxable income per capita. The measure was computed for each county and is defined as the wage and salary income earned by residents and non-residents in Wisconsin and the Wisconsin residents out of state. It also includes income earned from business ventures, partnerships, and from farm or rental property located in Wisconsin. The measure does not include transfer of payments such as social security payments, unemployment compensation or welfare benefits. (See Vol. 1, p. 1 of "Wisconsin Socio-Economic Indicators-1971".) (Also see Hiestand and Millard, 1971.)

In an effort to distribute Higher Education services, it is important to recognize the ability to pay. The regions of the state vary quite dramatically in this regard. The statewide average income per capita is

$2,981. It ranged from a high in Ozaukee County of $3,902 to a low in Menomonee County of $1,052. For this phase of the study, each of the counties were digitized (the independent variables U and V were measured from an arbitrary origin located southwest of the state).

The dependent variable was the 1969 measure of per capita income. These measures were processed through the trend surface analysis and produced a surface which explains 71% of the total sum of squares. This is analogous to a multiple correlation coefficient of .84. The map is a close fit to the surface trends which indicates an accurate depiction.

The map (see figure 7) indicates a gradual trend from the southeast to the northwest. The contour lines are expressions of percentage of the state mean per capita income. The state mean is expressed by a line passing through Manitowoc County southwest through Fond du lac, Dodge, Jefferson and Dane counties. It then breaks sharply to the southeast through Rock, Walworth, Racine and Kenosha counties along the southern border of the state. Typically, the urban areas to the east of this line show a higher per capita income than the rest of the state. The bulge in the line toward the west is undoubtedly due to the influence of Dane County which contains Madison, Wisconsin, the state capital. The northwest and southwest extremes of the state reflect the lowest per capita income with figures 35% lower than the mean. The population centers follow a similar pattern which substantiates that a significant proportion of the taxable income is generated in the south and southeast portion of the state.

The property tax paid per capita is a reflection of one of the financial drains on moneys generated. Not surprisingly, the pattern of per capita property tax reflects a pattern quite similar to per capita income. One would judge that the property tax admits to a higher degree of local variation because only 49% of the total sum of squares is explained. The state mean property

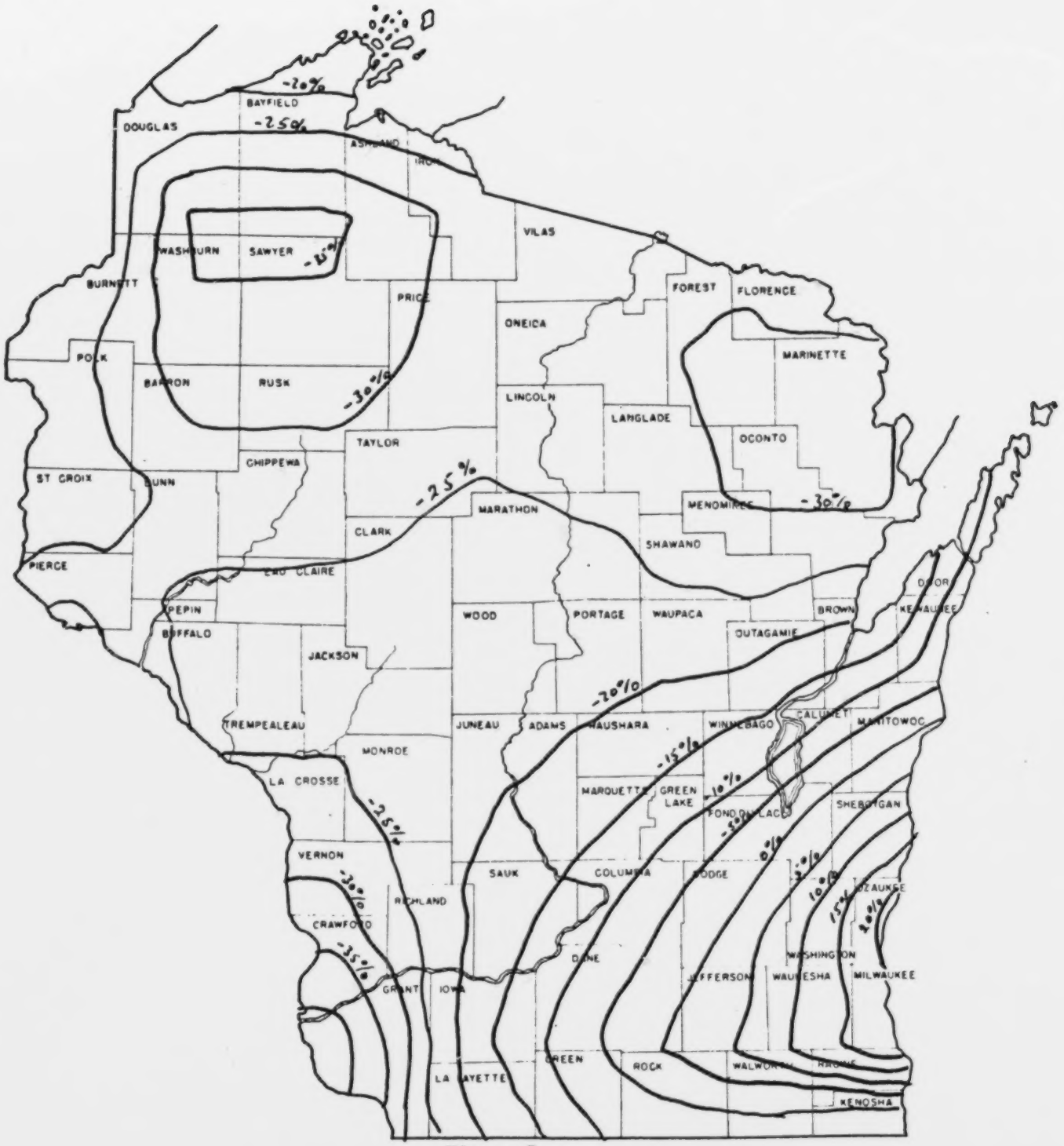

Figure 7

PER CAPITA INCOME AS A PERCENTAGE OF THE STATE MEAN
5th DEGREE TREND SURFACE
71% SS EXPLAINED

tax per capita was $266.86. While the overall trends for support of public services through property tax are useful for overall impressions, it is useful to know that the local effects reveal some interesting facts. Menomonee County, which enjoyed the lowest per capita income, pays the highest per capita property tax. Ozaukee County, on the other hand, which enjoyed the highest per capita income ranked 9 (of 72) in per capita income tax. Ozaukee County is supporting its share of public service, while Menomonee County demonstrated a herculean effort. Other counties, La Crosse for example, enjoy a rank of 62 in per capita property tax with an average of $182.75 and rank 27 in per capita income with $2,601 per capita.

The per capita full valuation (equalized valuation) is another measure indicating ability to pay. (See figure 9.) In Wisconsin, it follows a pattern similar to the per capita tax. This is not surprising, since the two figures are closely related. Per capita full valuation admits to more local effect than either of the prior maps. It is not surprising that Menomonee County ranks last in full valuation, but the effort to raise local funds is again magnified.

The state average for per capita full valuation covers a broad area in the center of the state. The average property tax per capita was nested in the southeast, indicating that the valuations per capita trend more with the state average in the central portion but the willingness of the population to pay does not. Since the per capita income for the same region is 20 to 30 percent below the state mean, it is not surprising.

The trend surface analysis provides a visual depiction of tax and income parameters across the state. The uses to which these data may be put are reserved to the policy group responsible for decisions. While the overall trends may be useful for examining the broad low frequency regional trends, it is important to recognize that local effects are not illustrated

Figure 8

PROPERTY TAX PER CAPITA AS A PERCENTAGE OF THE STATE MEAN
5th DEGREE TREND SURFACE
47% SS EXPLAINED

Figure 9

PER CAPITA FULL VALUATION AS A PERCENTAGE OF THE STATE MEAN
4th DEGREE TREND SURFACE
38% SS EXPLAINED

on the map. Additional tables regarding the residual or local effects are necessary adjuncts to the analysis.

Population Descriptors and Trend Surface Analysis

In addition to the fiscal data about the state constituency, other factors may be useful in the policy decisions for higher education. Dependency rates are often considered an inverse measure of ability to support public service. If that is so, the central, northern, and southern regions of the state demonstrate a high ratio and therefore a commensurate drain on personal income which is then not available for public service. High dependency ratios may also indicate a high need for support of higher education if the dependents are of college age. (See figure 10.) The trend surface explains only 29% of the sum of squares indicating a relatively low quality map admitting to local variation. The regression model is analogous to a multiple R of .54.

Dane County demonstrates a substantial deviation from the surface. The actual percentage of state mean dependency ratios was -120% indicating an extremely low dependency rate. It was, in fact, the lowest in the state. Dependency ratio is the total proportion of persons 1 month to 18 years plus persons 65 and over compared to the working population. The lower the dependency rate, the more a county is able to support public services. Menomonee County had the worst dependency ratio. Coupled with their low income rate and high unemployment, Menomonee County is in serious economic difficulty.

A second measure of interest to planners of higher education might be median school years completed. Such a measure reflects the historical dimension of educational experience. One might expect that regions demonstrating a history of educational achievement will continue to do so.

Figure 10

DEPENDENCY RATE AS A PERCENTAGE OF THE STATEWIDE MEAN
5th DEGREE TREND SURFACE
29% SS EXPLAINED

The map on median school years completed is a weak map admitting to much local variation. It shows a broad trend which is quite similar in pattern to the map for per capita income. The high of 12.05 years is located in Oazukee County and falls off to the northwest. A second high is apparent in the extreme northwest where Wisconsin joins the Minneapolis area of Minnesota. Highly urban centers apparently attract or produce populations with high priorities for education.

For obvious reasons, those counties with college or universities contribute significantly to the local effect. Dane County, the seat of the University of Wisconsin-Madison, has the highest actual median educational level of 12.60. The map does not accomodate this local variation.

Measures of unemployment illustrate expressions of local need which are not necessarily included in other measures. The eastern coast of Wisconsin along Lake Michigan enjoys the highest rate of employment. The state average for 1969 was 4% and small changes in this ratio produce drastic changes in the figures. Sheboygan, for example, is illustrated as 40% under the state mean. Therefore, their actual unemployment should be interpreted as 2.4%. Oneida County with a high of 80% of the State mean reflects an actual unemployment rate of 7.2%. The computed figures are based upon a state average and reflect the pattern across the state. The lowest rate of unemployment is near the urban centers, as indicated by the -40% in both the east and west extremes. The average unemployment region runs from Green Bay, through the Fox River Valley, through Dane County and on to the Southwest (see Figure 12).

Summary

Trend surface and other areal mapping techniques offer significant potential for providing information regarding broad regional bases. All

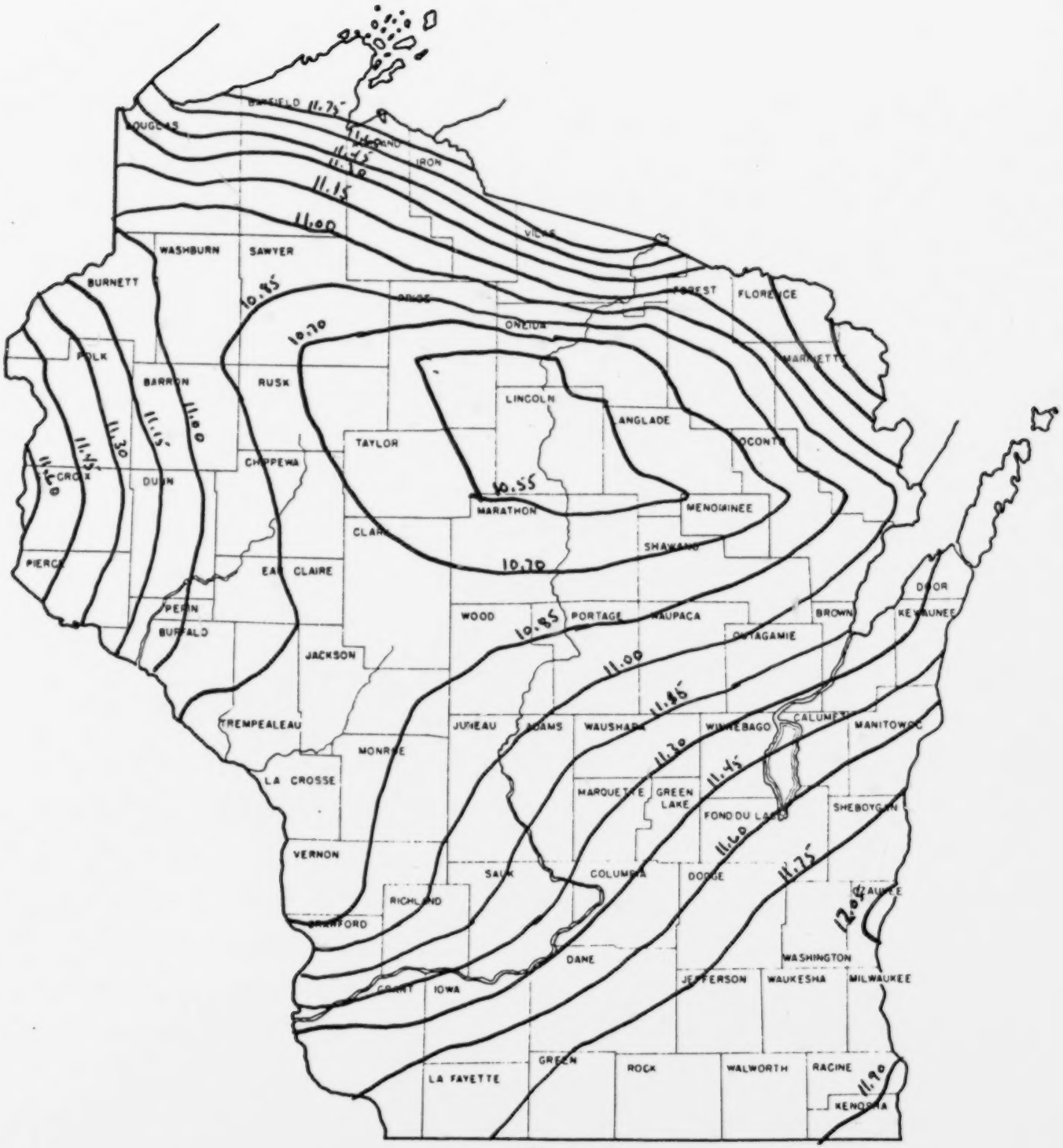

Figure 11

MEDIAN YEARS SCHOOL COMPLETED - PERSONS OVER 25
4th DEGREE TREND SURFACE
32% SS EXPLAINED

Figure 12
UNEMPLOYMENT AS A PERCENTAGE OF THE STATE MEAN
4th DEGREE TREND ANALYSIS
55% SS EXPLAINED

of the information displayed in the contour map is available in a number of tables. The interpretation of these data is greatly simplified when viewed as a map. A second advantage in the application derives from the ability to compare data drawn from various sources. The state maps presented in this paper have been drawn from two sources, the Wisconsin study of 1969 and aggregated county data. Much of the raw data is a matter of public record.

Additional sources may be considered. The survey Research Laboratory of the University of Wisconsin often polls the population through a carefully selected telephone sample. The area codes and telephone exchanges can be easily digitized to provide a geocode basis for producing maps. In order to adequately tap the attitudes of a state population, I would recommend a periodic telephone survey asking questions specific to the issues of Higher Education. Universities as well as other large public concerns need to sense the desires of the populations they serve. Studies of public demand are the first step on the road of accountability. Much data exists for analysis, but the essence of constituency desires for the roles of higher education can only be tapped by studies specifically designed to do so. Trend surface analysis offers a promising technique for interpreting the large volumes of data which accompany state-wide assessment.